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INFLUENCE OF THE MOON ON THE POSITION OF THE AXIS OF ZODIACAL LIGHT

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SUMMARY

The position of the axis of Zodiacal light has been studied on the basis of photoelectric observations of Zodiacal light made during 1955 - 1958. It is shown that on the average, this axis coincides with the ecliptic. - No relation is revealed between the position of the axis and the latitude of the point of observations. A dependence is found between the position of the axis and the ecliptical latitude of the Moon. Such a relation is possible if all or a considerable fraction of the material of Zodiacal light is located in the Earth-Moon gravity field.

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* *

The position of the axis of Zodiacal light has a first-degree significance for the theory of Zodiacal light. Its nearness to the ecliptic served as the first argument resorted to by Cassini [1] when explaining the Zodiacal light by scattering of solar radiation on particles of the heliocentrical dust cloud with maximum of particle concentration in the ecliptic plane. The old determinations of the position of the axis of Zodiacal light [2, 3, 4, 5 and 6] are based upon by sight estimates of brightness, without taking into account the influence of various components of night sky airglow, and thus can not represent sufficiently precisely the position of the axis of strictly the Zodiacal light.

(*) OS' ZODIAKAL'NOGO SVETA I VLIYANIYE LUNY NA YEYE POLOZHENIYE

The first instrumental determinations of the position of the axis of Zodiacal light, taking into account the night sky glow components, were made by Fesenkov [7] on the basis of observations carried out in 1913. These led him to the conclusion that the axis of Zodiacal light is parallel to the ecliptic, but is displaced from it by 2° northward. According to later photoelectric observations by Regener [8], the axis of Zodiacal light coincides with the ecliptic. A long series of photographic observations by Donich [9], carried out in Tamanrasset in 1946-1949, led him to conclude that the axis of Zodiacal light lies in a plane, inclined by 2° to the ecliptic at longitude of the ascending node 118°. Blackwell and Ingham reached practically the same result [10], having established on the basis of their photographic observations that the axis of Zodiacal light is inclined at an angle of 1.5° at ascending node longitude 115°. They reached the conclusion that the symmetry plane of scattered matter is near the invariable Laplace plane.

As may be seen from the results brought up by various authors, it is presently still difficult to reach a specific, sufficiently reliable conclusion as regards the position of the axis of Zodiacal light, inasmuch as these results are in many instances contradictory. In connection with this, we undertook the attempt of analyzing in detail the photoelectric observations, conducted by one of us during the period from 1955 to 1958. The description of observations setup and of material processing, together with the expounding of the general results of these observations, is brought out in the works [11, 12, 13, 14].

We understand by the axis of Zodiacal light the geometrical seat of the points of brightness maximum of Zodiacal light along cross sections perpendicular to the ecliptic. In order to search for these points, we utilized the extra atmospheric brightnesses of Zodiacal light, I_{Zod}, freed from the atmospheric and stellar glow components and dependent on the ecliptical latitude β and longitude $\varepsilon = |\lambda - \lambda_{\odot}|$, counted from the Sun ($\lambda$ and $\lambda_{\odot}$ being the ecliptical longitudes of the observed point of Zodiacal light and Sun, respectively).

For the determination of the axis of Zodiacal light the most convenient are the observations carried out at normal position of the ecliptic relative to the horizon. In this case the effect of tropospheric scattering is symmetrical relative to the ecliptic. As was shown by Fesenkov [15], at normal position of the ecliptic relative to the horizon the corrections for the scattering of Zodiacal light in the terrestrial atmosphere in the given almucantar is identical for the points situated at equal distances from the ecliptic, and therefore, the scatteringeffect of Zodiacal light in the terrestrial atmosphere does not displace the axis of the former, inasmuch as it is close to the ecliptic.

The photoelectric observations of 1957 were conducted in Egypt near Aswân, where in the morning hours the ecliptic was nearly perpendicular to the horizon. According to the found values of

$$I_{Zod} = f(\varepsilon, \beta)$$

for various cross sections $\varepsilon = \text{const.}$, we constructed the curves of brightness of Zodiacal light $I_{Zod} = f(c, \beta)$ dependence on the eclitpical latitude β. We demonstrate one of such curves in Fig. 1 as an example. According to these curves we determined the latitude β_m of the point of brightness maximum for the given value $\varepsilon = c$. The values of β_m were examined separately for each night of observations. In Fig. 2 we indicate the positions of brightness maximum points for each night in the elongation interval $35° \leqslant \varepsilon \leqslant 90°$. (The blue and green

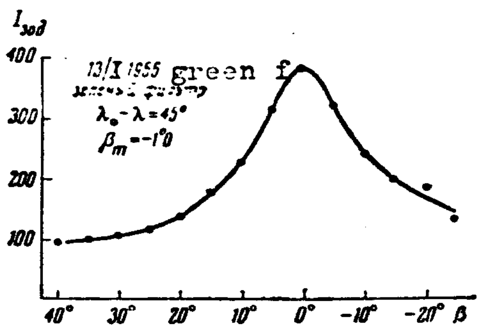

Fig. 1 - Curve of brightness dependence of Zodiacal light on the ecliptical latitude β along the circle $\varepsilon = \text{const.}$ (example)

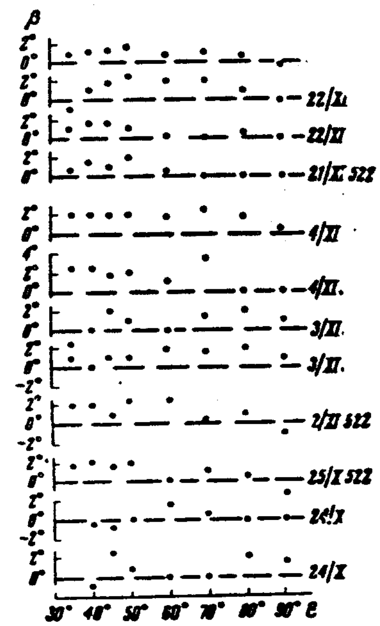

Fig. 2. - The dependence of β_m on ε according to observations of 1957.

filters are glass filters with with maximum transmission at respectively λ 414 and 541 mmk, the filter 522 is a narrow-band interference filter with transmission maximum at λ 522 mmk). As may be seen from the diagrams in the figures, these points are not disposed along a straight line that might be taken for the axis of Zodiacal light. It is quite possible that casual deflections are manifest here, which are conditioned by instrumental errors, and also by imperfection of the method of measurement processing. The fact is, that the existing method of liberation of the observed brightnesses on the atmospheric and stellar components is based upon averaged dependences. Thus, the liberation from the stellar component is carried out with the aid of the average dependence of the stellar component on the galactic latitude for the entire sky. At the same time, separate and not too bright stars, hitting the visual field of the photometer, can not be taken into account. However, they may introduce notable distortions. As to the atmospheric component, it is assumed constant along the almucantar. However, this last assumption, lying at the basis of the usually applied method of observations, is knowingly incorrect even in case when the ecliptic is perpendicular to the horizon. As is well known, the night sky airglow has a flocculent structure in the emission lines, which is quite difficult to take into account during the processing of observations of Zodiacal light. That is why the obtained positions of Zodiacal light brightness maximum may be deflecting from the position of the true maximum of Zodiacal light, distorting its axis.

If the position of the points of maximum brightness β_m as a function of ε is conditionally represented by the linear function $\beta_m = b\varepsilon + a$, we obtain for the parameters **a** and **b** the values compiled in Table 1* together with the values of the angle φ of these lines' inclination to the ecliptic ($\varphi = \mathrm{arctg}\, b$).

For the mean values by all nights and all filters we obtain the dependence $\beta_m = -0.018\ \varepsilon + 2^\circ.1$. which gives for the inclination of the mean axis to the ecliptic an angle $\varphi = -1^\circ.0$. As may be seen from Table 1, the positive inclination of the line, representing the axis of Zodiacal light, is obtained only in three cases and only for observations with a blue filter. For the green filter and for the interferometer filter 522 the inclination is negative in all cases, that is, near the horizon the points of brightness maximum of Zodiacal light are further deflected northward from the ecliptic, than in

* [see page 6]

the portions of the sky more remote from the horizon. Following are the mean values of β_m for all nights of observations (86 cross sections in all) :

$$\bar{\beta}_m = +1\overset{\circ}{.}1 \pm 0\overset{\circ}{.}15 \quad \text{for green rays}$$
$$\bar{\beta}_m = +1\overset{\circ}{.}0 \pm 0\overset{\circ}{.}2 \quad \text{for blue rays}$$
$$\bar{\beta}_m = +1\overset{\circ}{.}05 \pm 0\overset{\circ}{.}11 \quad \text{for green and blue rays}$$

Therefore, the data obtained according to 1957 observations in Egypt, allow the following conclusions. In the elongation region from 35 to 90° the points of brightness maximum of Zodiacal light are somewhat displaced northward of the ecliptic (by 1° as an average). However, this deflection is not identical for all elongations, which leads to a small inclination of the axis of Zodiacal light to the ecliptic at $\varepsilon = 120^{\circ}$.

The considered observations were conducted with filters, but without polaroid. Measurements with polaroid (three positions of the polaroid), which provide a nonpolarized as well as a polarized components, are less precise. The position of brightness maximum points obtained by these polarization measurements, are characterized by substantially greater point scattering, and that is why the axis is determined less reliably. Nevertheless, let us point out that the results of polarization measurements do not contradict the measurements without the polaroid.

It is of interest to compare the results of observations conducted in Egypt at vertical position of the ecliptic with the results of observations at its inclined position relative to the horizon. Such observations were conducted by one of us on the Kamenskoy Plateau at 1450 m altitude above sea level, and in 1958 — at the high-altitude station DAISH at 3000 m above sea level under perfect atmospheric conditions. We bring forth hereafter the mean dependences of β_m on ε together with the values of inclination angle of the axis of Zodiacal light to the ecliptic. All the considered observations were conducted in autumn (October-November) and refer to the morning Zodiacal light.

$$1955 \text{ r.} \quad \beta_m = +0.128\,\varepsilon - 9\overset{\circ}{.}3 \quad (\varphi = +7\overset{\circ}{.}3)$$
$$1956 \text{ r.} \quad \beta_m = -0.019\,\varepsilon - 0\overset{\circ}{.}9 \quad (\varphi = -1\overset{\circ}{.}1)$$
$$1958 \text{ r.} \quad \beta_m = -0.049\,\varepsilon + 3\overset{\circ}{.}9 \quad (\varphi = -2\overset{\circ}{.}8)$$
$$1957 \text{ r.} \quad \beta_m = -0.018\,\varepsilon + 2\overset{\circ}{.}1 \quad (\varphi = -1\overset{\circ}{.}0)$$

TABLE 1

DATE	FILTER	a	b	φ
24 X 1957	green	+1°5	−0.0080	−0°5
24 X 1957	blue	−0.77	+0.0135	+0.8
25 X 1957	522	+0.92	−0.0046	−0.3
2 XI 1957	522	+4.1	−0.046	−2.6
3 XI 1957	green	+2.1	−0.016	−0.9
3 XI 1957	blue	−1.2	+0.033	+1.9
4 XI 1957	green	+4.0	−0.040	−2.3
4 XI 1957	blue	+1.0	−0.017	−1.0
21 XI 1957	522	+2.2	−0.025	−1.5
22 XI 1957	green	+2.2	−0.026	−1.5
22 XI 1957	blue	+1.0	+0.0018	+0.1

As may be seen from these data, there is a good coincidence between the results of observations of 1956 conducted on the Kamenskoy Plateau, and those of 1957, conducted in Egypt, although the correction for the tropospheric scattering was taken constant in both cases along the almucantar. The result of 1958 differs little from the above. All these observations point to a small negative inclination of the axis of Zodiacal light to the ecliptic. However, according to polarization measurements of 1955, the inlination of the axis to the ecliptic was found to be positive and substantially greater than in subsequent years. Taking into account the good agreement of the results of 1956, 1957 and 1958, and without further observations, it is difficult to estimate to what extent the inclination is real from the observations of 1955, provided we bear in mind that, as pointed out above, the polarization measurements are less precise than those without polaroid.

TABLE 2

YEAR	$\bar{\beta}_m$	Δ	n
1955	−2°0	0°5	25
1956	−1.1	0.3	20
1957	+1.1	0.1	55
1958	+1.0	0.5	21

Taking into account that the inclination of the axis of Zodiacal light is significantly influenced by the above indicated errors of observations and processing methods, the mean night values $\bar{\beta}_m$ of point latitudes of brightness maximum of Zodiacal light along the cross sections $\varepsilon = \text{const}$ can serve as a more reliable characteristic of the position of the axis of Zodiacal light. The cross sections $\varepsilon = \text{const}$ were obtained by reduced true brightnesses of Zodiacal light, freed from all the components of night sky glow and represented in the form of a function $I_{Zod}(\beta, \varepsilon)$

of the ecliptical latitude β_m and longitude differences $\varepsilon = |\lambda_{\odot} - \lambda|$. The mean values β_m for every year of observations in green rays are brought out in Table 2 alongside with the mean quadratic ones Δ. In the last column of the table we indicated the number of cross sections n, according to which the averages were obtained.

As is shown by the data of Table 2, there is no essential departure in the position of the axis of Zodiacal light, either from observations in Egypt (Aswân) at $+24^{\circ}$ geographic latitude and Alma-Ata (geographical latitude $+43.2^{\circ}$). The mean ecliptical latitude of the points of brightness maximum for the period 1955-1958 according to observations in green rays was found to be $-0.2^{\circ} \pm 0.8^{\circ}$. The mean weighted according to all observations gives $+0.1^{\circ} \pm 0.2^{\circ}$. Therefore, our results show that within the limits of the precision of observations, the axis of Zodiacal light coincides, as an average, with the ecliptic.

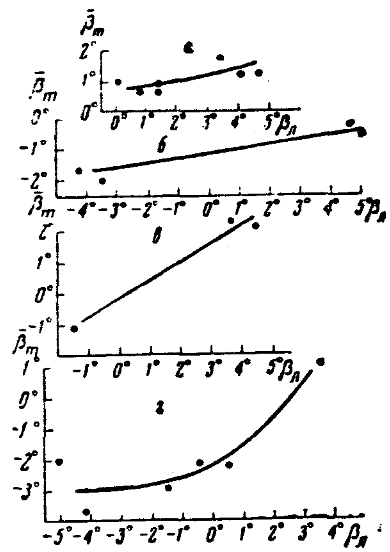

Fig. 3. - Relationship between β_m and β_{Λ} according to every year's observations in green rays. - a — 1957; — 1956; — 1958; — 1955.

The investigation of deflections of the mean nocturnal values $\bar{\beta}_m$ has permitted to establish a link between the average night latitude $\bar{\beta}_m$ of the points of

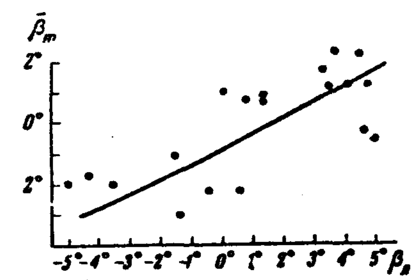

Fig. 4. - Relationship between $\bar{\beta}_m$ and β_{Λ} according to 4-year observations 1955 - 1958.

brightness maximum and the latitude β_{Λ} of the Moon. The relationship between the mean ecliptical latitude β_m of the points of brightness maximum (for the given night) and the ecliptical latitude β_{Λ} of the Moon is shown separately for each year in Fig. 3. These results refer to observations in green rays. As may be seen from Fig. 3, the latitude of the points of Z.l. brightness maximum increases in all cases, as the latitude of the Moon increases.

In Fig. 4 we assembled all the four-year observations. The dependence of β_m on β_{Ω} is evident here too. The correlation factor between β_m and β_{Ω} was found to be 0.76 for all the nights of observations during the entire four-year period. If the mean values of β_m are computed taking into account the weight, imparting to each determination a weight proportional to brightness, the result will not be changed qualitatively. In this case the correlation factor will be found to be 0.75, which practically coincides with the above.

The dependence of β_m on β_{Ω} detected by us, is found to be in agreement with the earlier found [16] dependence of the brightness of Zodiacal light on the age of the Moon and shows that the Moon affects the matter conditioning the Zodiacal light. It is evident that this may be only in the case when this matter is located near the Moon and is subject to the action of its gravitational field. Note, however, that the axis of Zodiacal light does not coincide with the lunar orbit plane, but lies in the ecli ic or very near it. Therefore, the Moon exerts a perturbing action upon the matter of Zodiacal light, deflecting its axis on either side of the ecliptic. This result may have a great significance for the study of the nature of the substance of Zodiacal light and shows that if not all its brightness, at least its essential part is conditioned by the scattering of solar radiation over the dust matter located in the gravitational field of the system Earth-Moon.

**** THE END ****

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